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Assessment of COWFISH for Predicting Trout Populations in Grazed Watersheds of the Intermountain West

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CONTENTS

Introduction 1
Model Description 2
Study Areas 2
Methods 8
  Using the Manual 8
  Data Used for Testing 8
  Modifications 10
  Sensitivity 10
Results 10
  Mechanics of the Model 10
  COWFISH Without Modifications 10
  Modifications 18
  Sensitivity 23
Discussion 23
  Mechanics of the Model 23
  COWFISH Without Modifications 23
  Modifications 24
  Sensitivity 25
  Current Status of COWFISH 25
Summary 25
References 26

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INTRODUCTION

Western public rangelands are primarily administered by the U.S. Department of Agriculture, Forest Service, or the U.S. Department of the Interior, Bureau of Land Management. Consequently, management of these rangelands is subject to Federal legislation designed to protect public resources and promote a diversity of use. These acts include the Multiple-Use Sustained Yield Act of 1960 (PL 86-517), the Forest and Rangeland Renewable Resources Planning Act of 1974 (PL 93-378), the National Forest Management Act of 1976 (PL 94-588), the Public Rangelands Improvement Act of 1978 (PL 95-514), and the Soil and Water Resources Conservation Act of 1977.

Livestock grazing is a historic and time-honored use; however, it is also a potentially destructive practice. In recent years, attention has become focused on the relationships between livestock use of riverine riparian areas and the degradation of trout habitat. In order to fulfill multiple-use management responsibilities, the Forest Service has developed models that attempt to predict the effects of land management activities on riverine riparian systems and associated fish populations. Federal agencies like the Forest Service generally manage fish habitat rather than fish populations. Consequently, fisheries resource models generally attempt to evaluate habitat conditions first and then relate these conditions to fish populations.

COWFISH (Lloyd 1986) is a model designed to estimate livestock impacts on stream-riparian features and to estimate impacts on fish abundance and fisheries economic values. COWFISH is listed as a working model by the United States Environmental Protection Agency (EPA) (USDI-EPA 1987). It is patterned after the U.S. Fish and Wildlife Services's Habitat Suitability Index (HSI) Model Series (Hickman and Raleigh 1982). The EPA (1987) reports that COWFISH was designed for conditions in Montana, but that it is usable, with alterations, throughout the Western United States. The EPA publication neither cites prior testing of COWFISH nor identifies what adjustments may be needed to use it in areas other than western Montana or with fish other than Rainbow trout. Lloyd (1986) cautions against its use (without adequate testing and modification) outside of the mountainous regions of central Montana where it was developed. Furthermore, Lloyd (1986) states that it is a "relational model and not based on cause and effect." Because the model's estimates of fish populations do not reflect actual fish populations and because of Lloyd's (1986) "relational restriction," it is not appropriate to use the fish abundance and economic loss portions of the model. The habitat suitability index may be useful as a general indicator of stream-riparian health.

Our objective was to apply the COWFISH model to a variety of streams in the Intermountain West to determine its capability to estimate fish populations in grazed watersheds. During the last decade, fisheries researchers at the Intermountain Research Station have assembled a large data base. We applied COWFISH to study sites (sites with concurrent fish population and physical habitat data) as it stands in the manual, and later with alterations recommended by COWFISH users. The only other testing known to date is that done by Shepard (1989) in Montana. Shepard found that COWFISH explained 65 percent of the variation in rainbow and cutthroat trout abundance ($r^2 = 0.65$) for the streams he tested but only 14 percent for brook trout ($r^2 = 0.14$).

MODEL DESCRIPTION

The COWFISH manual states that its main purpose was to alert range managers to the impacts livestock can have on stream-riparian habitat and trout populations. COWFISH, in design, estimates monetary loss and fish loss due to livestock impacts based on seven habitat attributes by comparing estimates of optimum and existing numbers of catchable trout in a stream reach, regardless of species. Catchable-trout are classified as those longer than 6 inches. Optimum number of catchable trout is defined as the number that would have been present if the stream had never been grazed by domestic livestock. Existing numbers of catchable trout are the numbers present under the current management situation. COWFISH then estimates the difference between the estimated optimum and estimated existing number of catchable trout. This difference is the estimated "fish loss" due to livestock use. To calculate total economic loss, COWFISH assigns $10.65 for each fish lost. Recreational loss is estimated by dividing the number of fish lost by 6 (one wildlife-user-day was defined to be worth $63.87 and six fish are caught in the average wildlife-user-day, USDA 1985). The seven habitat input variables estimated ocularly are:

1. Percentage of undercut bank
2. Percentage of overhanging vegetation
3. Percentage of trampled vegetation or exposed soil on the bank; (termed alteration)
4. Percentage of riffle area covered by fine sediments; (termed embeddedness)
5. Stream width-depth ratio
6. Stream gradient
7. Parent rock type.

COWFISH's capabilities are reported as:

1. COWFISH, with adjustments, is reported to be applicable throughout the Western United States, "since impacts occurring along streams from livestock grazing are similar from one geographic area to another" (Lloyd 1986).
2. The model can be used any time there is not snow cover, but it is best if used immediately after the grazing season.
3. The model can be used to evaluate large homogeneous stream sections (data collected from five different sites per stream mile are needed to provide a 10 percent sample of the study area).
4. The model is most suitable for streams less than 18 feet wide with low channel gradients, erodible banks, and grass-forb-sedge riparian areas.
5. The model can be used successfully by untrained personnel using ocular estimations.

COWFISH's limitations are reported (Lloyd 1986) as:

1. Accuracy of results diminishes when the estimation of grazing impacts of fish production does not immediately follow the grazing season.
2. The model is less accurate for those streams with rocky streambanks, widths greater than 18 feet, channel gradients over 5 percent, and with forested riparian zones.
3. The model outputs reflect population numbers for the immediate area sampled and not for the complete stream (sample designs in heterogeneous sections must be determined by the evaluators).

Assumptions of COWFISH, either stated or implied, are:

1. Fish populations are dependent upon or correlated with those physical habitat features that COWFISH estimates.
2. Fish populations are sufficiently independent of prior years, conditions up and down stream, other species, and intrinsic population dynamics.
3. Users will estimate stream-riparian attributes with sufficient accuracy and precision.
4. The variables and procedures used to calculate economic values are reliable.
5. Minor violations of the above assumptions do not render the model useless.

STUDY AREAS

Study sites included 21 to 62 transects on each of 44 sites on 14 streams over the course of 12 years, in Idaho, Utah, and Nevada (table 1 and fig. 1). Three or four sites on a stream reach constituted a study area. Each transect includes measurements from the right and left banks. All sites had gradients less than 5 percent. The geographic diversity of our study areas provided a wide range of environmental conditions and species assemblages.

The Idaho study streams were generally sinuous and flowed through wet meadows in granitic valleys formed mainly by Pleistocene glaciers. Mean stream width ranged from 5 to 33 feet (table 1, figs. 2-4). Fish species included resident populations of bull trout (*Salvelinus confluentus*), brook trout (*S. fontinalis*), rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), sculpins (*Cottus* spp.), and anadromous populations of steelhead trout (*O. mykiss*), and chinook salmon (*O. tschawytscha*).

The Utah and Nevada study sites were less sinuous, occurred in nongranitic drainages, and flowed through drier meadows or canyons with valley floors approximately five to 50 times wider

than the bank-full stream width. Average stream widths in Utah ranged from 13 to 15 feet. Average stream widths in Nevada ranged from 4 to 14 feet (table 1, figs. 5-8). Fish species included resident populations of cutthroat trout (*O. clarki*), wild and hatchery-reared brown trout (*S. trutta*), rainbow trout, brook trout, sculpin, daces (*Rhynichthys* spp.), redside shiner (*Richardsonius balteatus*), and suckers (*Catostomus* spp.).

Table 1—Study site information; stream numbers conicide with figure 1 and figure 20

Region	Stream	Game species present (>6 inches)	Mean width	Gradient	Site	X = Year sampled 75	76	77	78	79	80	81	82	83	84	85	86
			Feet	*Percent*													
Idaho Batholith; Granitic																	
1	Johnson Creek	Brook trout	10	0.18	1	X	X	X	X	X	X	X	X	X		X	
				.18	2	X	X	X	X	X	X	X	X	X		X	
				.06	3	X	X	X	X	X	X	X	X	X		X	
2	Stolle Meadow	Bull trout	15	.45	1	X	X	X	X	X	X	X	X	X	X	X	
				.47	2	X	X	X	X	X	X	X	X	X	X	X	
				.51	3	X	X	X	X	X	X	X	X	X	X	X	
3	Bear Valley, U	Brook trout	26	.25	1		X	X	X								
				.28	2		X	X	X								
				.09	3		X	X	X								
4	Bear Valley, L	Brook trout	33	.29	1		X	X	X	X	X						
				.09	2		X	X	X	X	X						
				.10	3		X	X	X	X	X						
5	Frenchman, U	Brook trout	16	.62	1			X	X								
				.44	2			X	X								
				.11	3			X	X								
6	Frenchman, L	Brook trout	12	.32	1		X	X	X	X	X	X	X	X			
				.53	2		X	X	X	X	X	X	X	X			
				.55	3		X	X	X	X	X	X	X	X			
7	Horton Creek	Brook trout	5	2.32	1			X	X	X		X	X	X			
				1.42	2		X	X	X	X		X	X	X			
			5	1.20	3		X	X	X	X		X	X	X			
Nevada Streams; Nongranitic																	
8	Gance Creek	Cutthroat trout	6	2.23	1				X	X	X	X	X	X	X	X	X
				2.66	2				X	X	X	X	X	X	X	X	X
				2.21	3				X	X	X	X	X	X	X	X	X
9	Chimney Creek	Cutthroat trout	5	4.16	1							X	X	X	X		
				2.74	2							X	X	X	X		
				2.65	3							X	X	X	X		
10	Tabor Creek	Rainbow trout	14	.85	1					X	X	X	X	X	X		
				2.49	2					X	X	X	X	X	X		
				1.60	3					X	X	X	X	X	X		
11	Deer Creek	Cutthroat, rainbow, brook trout	4	2.93	1												X
				1.39	2												X
				3.49	3												X
				2.74	4												X
12	Big Creek, Upper	Brown, rainbow trout	13	.78	1							X	X	X		X	
				.65	2							X	X	X		X	
				.79	3							X	X	X		X	
				.80	4							X	X	X		X	
13	Big Creek, Lower	Brown, rainbow trout	13	.63	1					X	X						
				.82	2					X	X						
				.32	3					X	X						
14	Otter Creek	Brown, rainbow trout	15	.29	1					X	X	X	X	X			
				.26	2					X	X	X	X	X			
				.18	3					X	X	X	X	X			

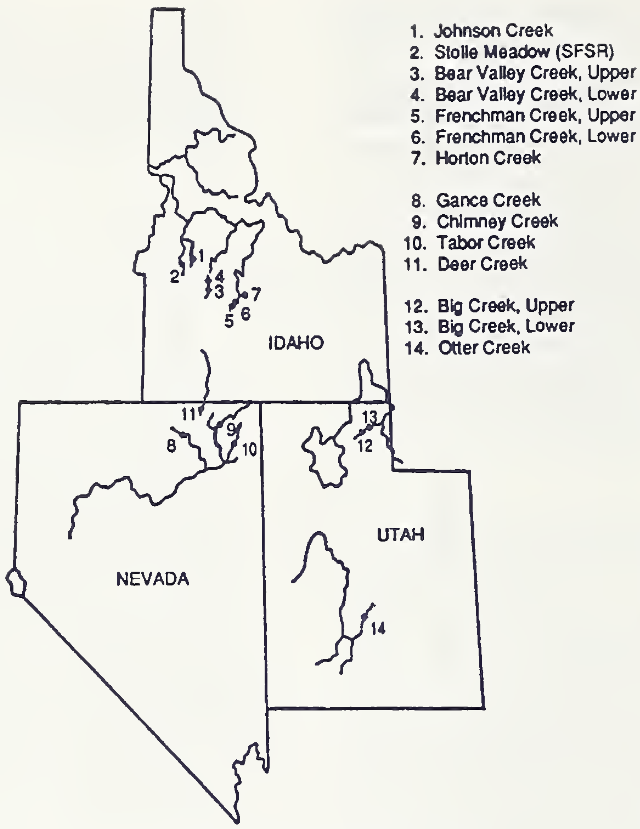

Figure 1—The location of the study streams in the Intermountain West.

Figure 2—Bear Valley Creek.

Figure 3—Horton Creek.

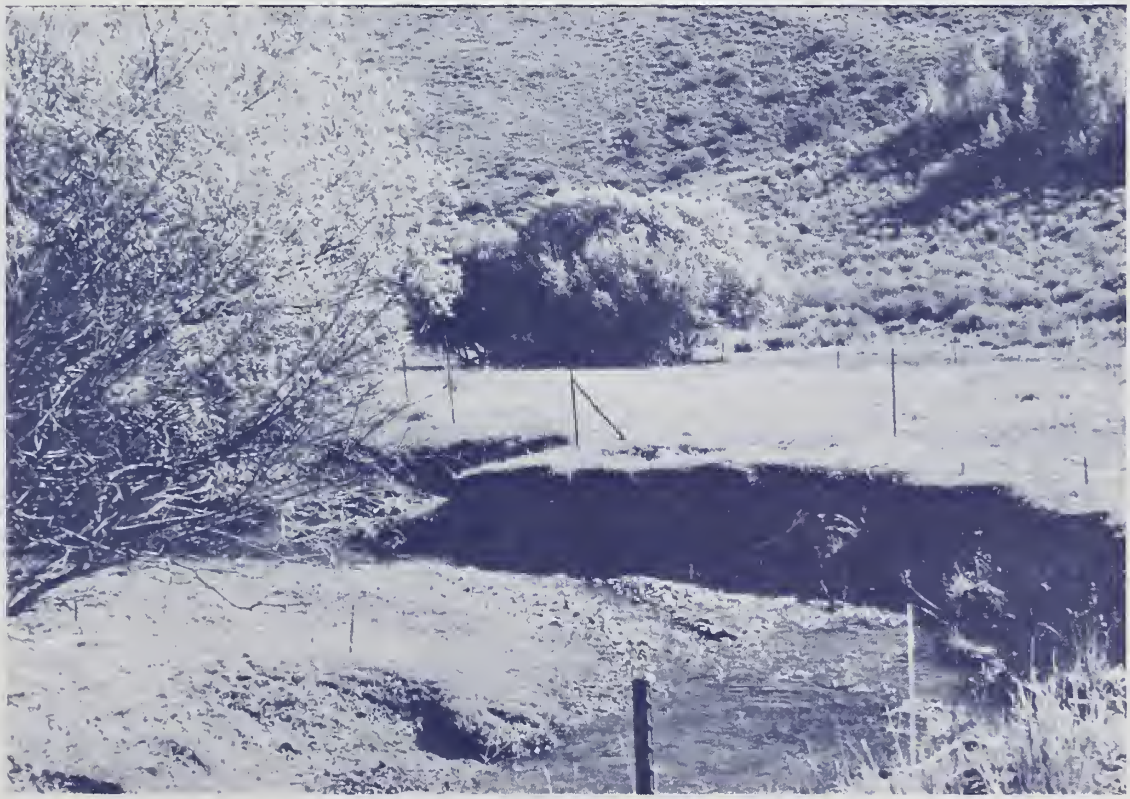

Figure 4—Gance Creek.

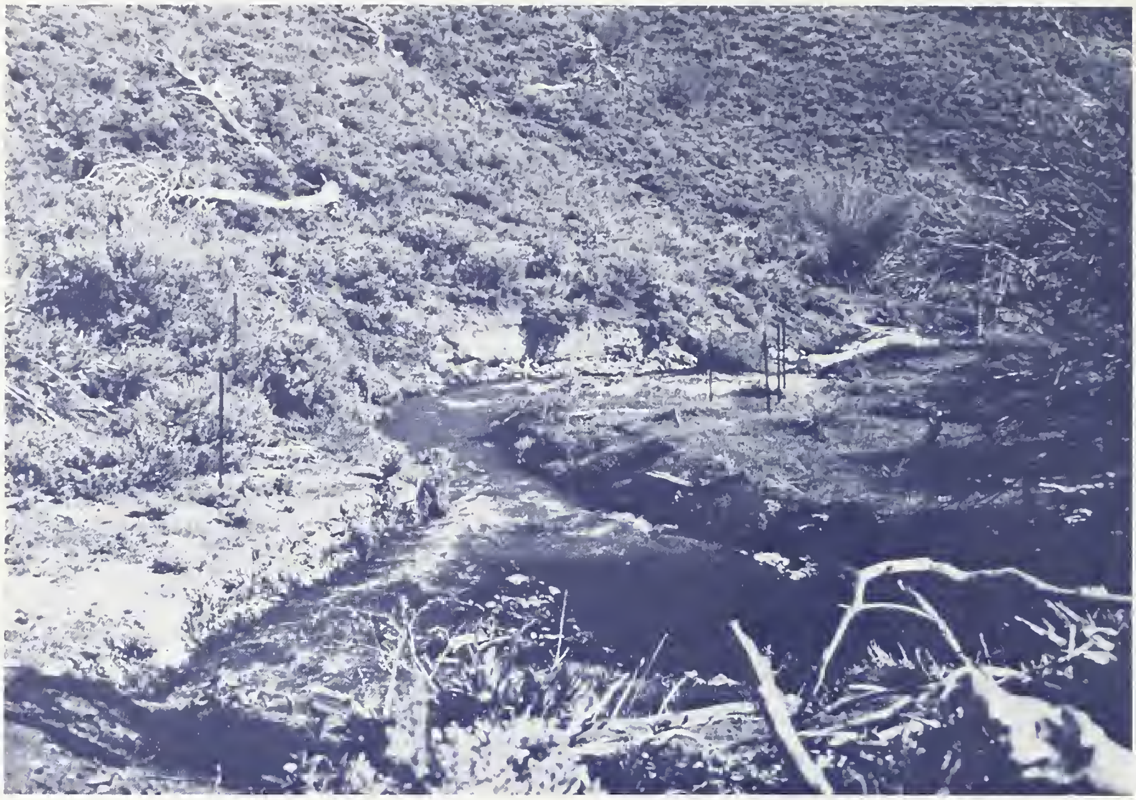

Figure 5—Chimney Creek.

Figure 6—Big Creek.

Figure 7—Big Creek.

Figure 8—Otter Creek.

METHODS

Using the Manual

To test COWFISH, as it stands in Lloyd (1986), we worked through the manual and worksheets by hand to check for clarity, usability, and consistency. Anadromous fish were excluded from our analysis even though they were sympatric with resident trout in some of the Idaho streams. Juvenile anadromous fish were shorter than the 6-inch minimum length requirement for catchables. We built a BASIC program that synthesized the mechanics of the manual and worksheets as if the data from each site were calculated by hand. Each data set contained a fish population estimate that had been collected concurrently with the physical measurements. The program mimics the manual by rounding continuous raw data into "Parameter Suitability Indexes" (PSI). We used coefficients in calculating "optimum fish/984 feet (300 m)" from "optimum stream width" instead of using the graphs by hand as provided in the manual. In the manual the plot appeared to be a straight-line function passing through the origin. This function can be represented with a singular coefficient. Four coefficients were used depending on parent rock type and steam gradient according to the plots.

The four functions were derived from the plots as no coefficients were given in the manuals we received. Derived coefficients were: $Y = 0.8X$ and $Y = 1.6X$ for granitic drainages with stream gradients greater than or less than 5 percent, respectively, and $Y = 2.5X$ and $Y = 5.0X$ for nongranitic drainage with stream gradients greater than or less than 5 percent, respectively, where X = the optimum steam width and Y = the optimum number of catchable trout/984 feet.

Reviewers of an earlier manuscript provided the actual coefficients, which were 0.75 and 1.5 for granitic drainage, and 2.0 and 5.0 for nongranitic streams with gradients greater than and less than 5 percent, respectively. We also ran the analysis with the corrected coefficients and other improvements suggested by COWFISH users. But we remind the reader that COWFISH was first applied as it stands in the manual because that is most likely how it has and will be used.

The text of our manual deviated from the worksheet on two accounts. Line 8 of the calculation worksheet should include the statement of page 16 of the manual stating "for those samples with a PSI for the W/D ratio of 0.5 or less, use the value of 0.5 to multiply times the existing width to determine the optimum stream width." Furthermore, line 14 of the calculation worksheet, which reads "(line 12)/6," should read "(line 13)/6." Where discrepancies occurred, the BASIC program followed the algorithm of the text and not the worksheet. The COWFISH worksheet in GAWS (USDA 1986) has similar errors and should be checked with the text.

Data Used for Testing

To test COWFISH's implied assumption that the input and output variables relate to fish populations, we calculated and plotted regression line and data for each relationship as a descriptive method and visual indication of how well each variable explained electrofishing estimates of fish abundance. We estimated salmonid abundance in each stream site for each year by the removal-depletion capture strategy using multiple electrofishing passes within an enclosed section of stream. Electrofishing data were analyzed using Van Deventer and Platts' (1989) Mircrofish 3.0 PC software, which incorporates the maximum-likelihood method to estimate total abundance.

In addition to evaluating the capability of COWFISH to estimate fish abundance for each year and site in each stream, we calculated the grand mean for COWFISH and electrofishing abundance estimates for each stream for all years and sites.

Averaging several years together reduces the nuisance variables associated with sampling error and fluctuations of fish populations around a hypothetical mean carrying capacity. Comparing the mean of 7 or 8 years of electrofishing estimates with the mean of 7 or 8 years of COWFISH estimates could be a better test of COWFISH than using individual years.

Because fish populations can fluctuate widely over time (Platts and Nelson 1988), we also examined the average of electrofishing and COWFISH estimates of existing fish for individual streams (with 6 or more years of data) to minimize the effect of possible population fluctuations (table 5). For each site with 6 or more years data, we calculated the mean of the first 3 years separately from the second 3 years. This gave us two 3-year means for each of the three or four sites in a study area. We did not do this for sites with less than 6 years of data because we wanted at least two 3-year means for each site.

Physical habitat data were collected with standardized measurement techniques as described in Platts and others (1983, 1987). COWFISH's method calls for walking along the bank and visually estimating in percentage the occurrence of an attribute. Platts' method involved the development of transects and the measurement of attributes with geopoles, measuring tapes, and clinometers. To utilize the extensive data base at the Intermountain Research Station, we made the following assumptions:

(1) our methods are as good as or better than COWFISH's in estimating what is actually there; (2) the better data we have, the better COWFISH will estimate existing and optimal fish numbers; and (3) the success of COWFISH does not depend on observer error.

The COWFISH method for estimating percentage of undercut bank requires estimating the length of streambank that has a bank angle of less than 90 degrees for 100 feet of stream. Twenty feet of undercut on both sides would be 20 percent undercut for a 100-foot section of stream. We measured the actual angle and depth of the undercut on both banks at 21 to 62 transects for each site. To convert our data to approximate COWFISH's, we ignored the depth of the undercut banks and found the percentage of all banks that were less than 90 degrees.

COWFISH measures the percentage of vegetation of overhang in the same manner as undercut banks. We measured the percentage of vegetation as we did the percentage of undercut banks. Regardless if the vegetation overhang was 1 inch or 100 inches across the width of the stream, the rating would be the same if both occupied equal distances parallel to the stream.

The variable "altered banks" in COWFISH, as we interpreted it, was actually the percentage of the bank, on a linear basis, where soil was exposed. It did not address historic alterations that are lightly or heavily revegetated. We calculated the percentage of both banks on all transects with vegetation cover codes and habitat types that indicate bare soil as the dominant feature (Platts and others 1983). COWFISH users suggested that we include trampled vegetation to estimate the percentage of alteration. To do this we also used vegetation utilization estimates of 90 percent or greater as an indication of trampling.

For embeddedness, as we interpreted the manual, COWFISH deviates from the standard definition as defined by Platts and others (1983) and Helm (1985). COWFISH defines it as the "percent coverage of stream bottom by fine material 0.125 inches in diameter or less" or the percentage of surface area of the stream bottom that is 100 per-cent embedded. The manual includes a figure clearly showing this concept. The standard definition for percent embeddedness is the percent substrate particles are enveloped by fines having a maximum particle diameter of 0.125 inches or less. Therefore, we used our substrate inventory data (rather than embeddedness data) to calculate the percentage of the total stream width that is dominated by fine sediment.

COWFISH users suggested that COWFISH should be applied with the standard embeddedness as defined by Platts and others (1983). Therefore an additional analysis was run with mean standard embeddedness measurements for each site. COWFISH's embeddedness was determined only for transects classified as riffles as described in COWFISH. If few riffles were found in the entire reach, as defined by Platts and others (1983), we also included shallow glides. This is reasonable as some meadow streams have few riffles. We assumed that technicians would consider shallow areas as riffles. Under certain flow conditions slow riffles can be inadvertently described as fast glides. Therefore in the few sites where few riffles existed we also included shallow glides. We feel this is a reasonable estimate of COWFISH's stated embeddedness based on the description, figure, and the following statement about embeddedness from the manual: "This evaluation is to provide an estimate of fine material throughout the entire streambottom regardless of pool/riffle composition" (Lloyd 1986).

The COWFISH manual suggests an ocular estimate of mean width and depth without indicating how many estimates to make, where to make them, or at what flow. We measured width and mean depth (from four measurements) at each transect with a measuring rod and calculated a mean width to depth ratio for the site.

COWFISH also suggests estimating stream gradient ocularly. Gross estimates between gradients are fairly easy. But we measured site gradient with an engineer's level and stadia rod. We doubt that such precision was necessary.

To estimate the optimum number of fish in a reach, COWFISH requires the separation of drainages into granitic and nongranitic parent rock types. The gross classification of parent rock material of an entire drainage into two simple types can be difficult if actual geologic surface materials are considered. We based our decision on the estimate that one drainage was mostly granitic while another was mostly something else.

Although a tremendous amount of information was set aside in reducing the data, it allows the use of 230 data sets to assess COWFISH's utility in several Intermountain streams. We assume that our method of estimation is as acurate or more accurate than the ocular methods prescribed by COWFISH. We did not test this assumption. The range of variability associated with ocular estimations would probably include our measurements. Furthermore, if COWFISH is as robust as Shepard (1989) reports, then our methods would be even more reasonable.

Modifications

The COWFISH manual suggests that, with a few modifications, the model can be fine-tuned to work in any area. Therefore, after running the model, we performed correlation and linear regression analysis between actual fish present and COWFISH's input and output variables to determine whether any reliable coefficient could be used to improve the predictability of COWFISH in estimating fish abundance in our study streams.

The COWFISH manual reports that as the rock content of the streambank increases, the accuracy of the model decreases. Therefore, we compared the percentage of boulder and rubble content of the stream substrate to the difference in numbers of trout predicted by COWFISH and by electrofishing.

The model may be best used to predict relative fish abundance for individual streams and species, with modifications for each situation. Therefore we also investigated streams and species separately. Johnson and Frenchman Creeks were tested with brook trout, Otter Creek with hatchery brown trout, South Fork Salmon River at Stolle Meadows with bull trout, Gance Creek with cutthroat trout, and Tabor Creek with rainbow trout. Each stream had no other game fish species of catchable size, except for Otter Creek, which also had hatchery rainbow trout.

Sensitivity

Sensitivity analysis of COWFISH was performed by altering each input variable by 10 percent from 0 to 100 on individual runs through the model while holding all other things constant on data from lower Frenchman Creek. The changes in output from proportional changes in input were examined.

RESULTS

Mechanics of the Model

In evaluating the mechanics of the manual, we found inconsistencies between the worksheet and the text. Using worksheets from Lloyd (1986) and GAWS (USDA 1986), economic loss estimated for 984 feet of Tabor Creek varied from \$54.00 to \$271.00, depending on which inconsistencies were corrected. By following the text's algorithm, an economic loss of \$163.19 was estimated.

COWFISH Without Modifications

Only weak relationships were found between actual fish numbers and input or output variables used or calculated by COWFISH, including modifications suggested by COWFISH users (tables 2-3 and figs. 9-18). Although some significant correlations exist (mostly because of the large n size) between the input and output values and the estimated number of fish present, the variation was so large in all cases that there was no predictive utility in the relationships. Converting raw percentage of occurrence data into PSI values did not improve the strength of the relationships (table 3). The best relationship observed was between estimated fish abundance by COWFISH and electrofishing ($r^2 = 0.14$) in streams with nongranitic drainages, where 14 percent of the variation of fish abundance could be predicted by COWFISH (table 3).

Table 2—The relationship between measurements of stream attributes and actual number of fish from three- and four-pass electrofishing. All streams and fish species combined, $n = 230$

Measurement	r^2	r	p
Percent undercut bank	0.003	0.055	<0.50
Percent overhanging vegetation	.046	.214	<.005
Percent alteration	.047	.217	<.005
Percent embeddedness	.014	.118	<.10
Width-to-depth ratio	.001	.032	—

Table 3—The relationship between a stream attribute and actual number of fish calculated using three- and four-pass electrofishing. All streams and fish species combined

Stream attribute	Granitic (n = 132)			Nongranitic (n = 98)		
	r^2	r	p	r^2	r	p
Undercut bank PSI	0.027	0.16	<0.10	0.055	0.23	<0.05
Overhang PSI	.039	.20	<.05	.035	.19	<.10
Alteration PSI	.000	.00	—	.023	.15	<.20
Embeddedness PSI	.003	.05	—	.007	.08	<.50
Width/depth ratio PSI	.041	.20	<.05	.008	.09	<.50
Mean PSI	.042	.20	<.05	.014	.12	<.50
Optimum width	.001	.03	—	.091	.30	<.005
Optimum fish	.001	.03	—	.091	.30	<.005
Existing fish	.041	.20	—	.137	.37	<.001
Stream gradient	.081	−.28	<.002	.045	−.21	<.05

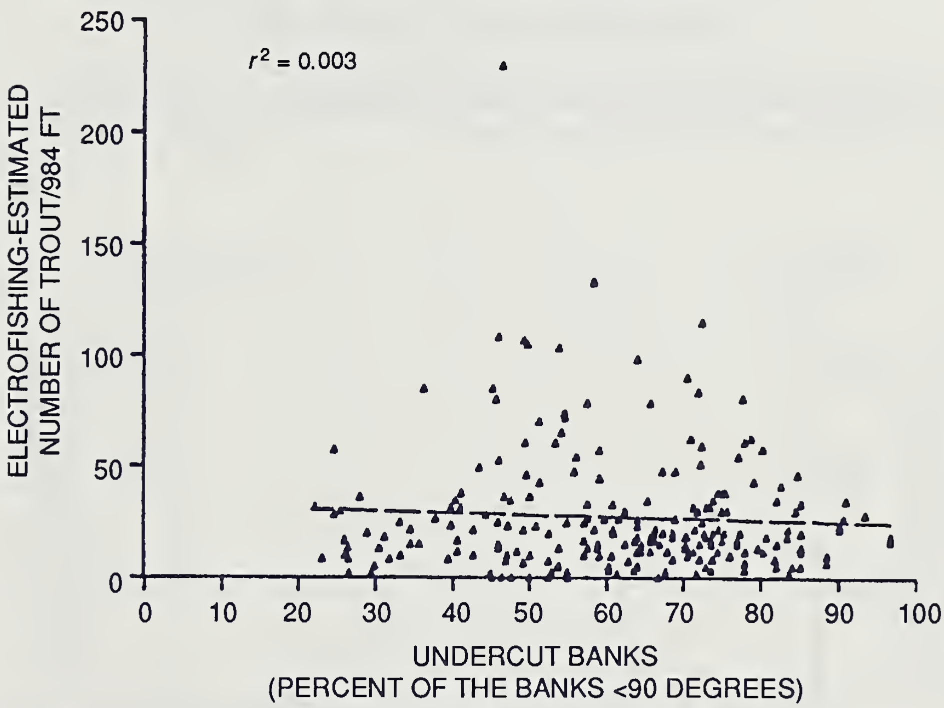

Figure 9—Relationship of the percentage of the banks with angles less than 90 degrees plotted against electrofishing-estimated numbers of trout longer than 6 inches, n = 230, all sites and years.

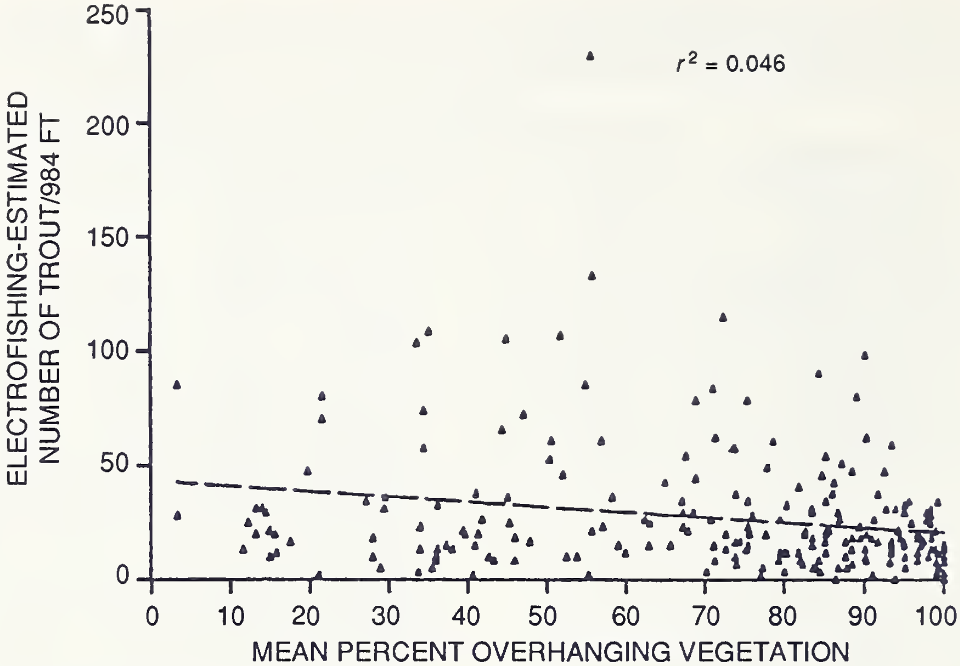

Figure 10—Percentage of the bank with overhanging vegetation plotted against electrofishing-estimated numbers of existing trout longer than 6 inches, $n = 230$, all sites and years.

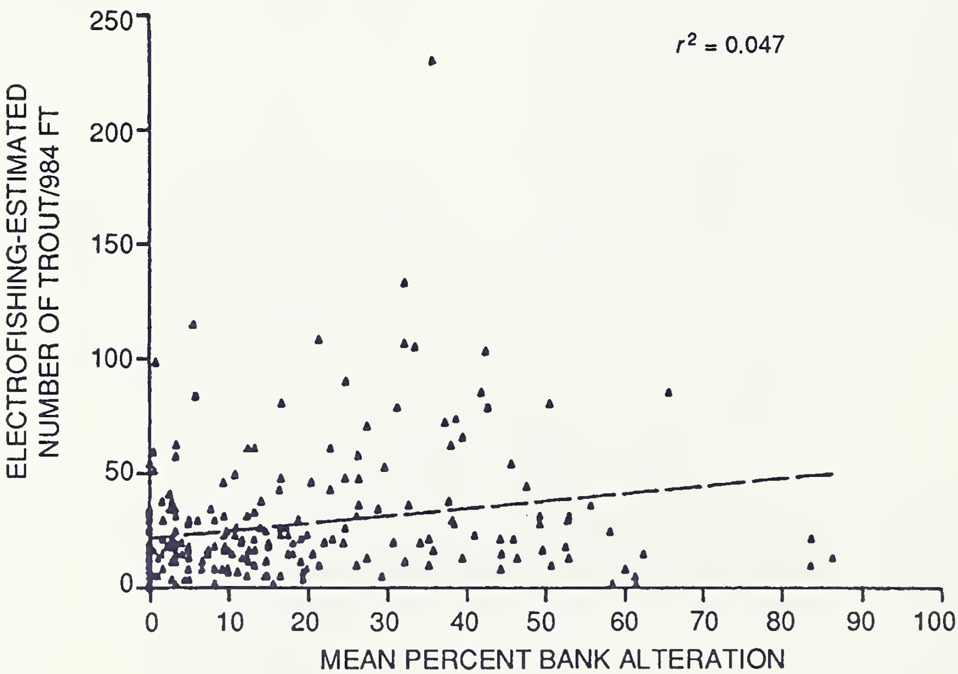

Figure 11—Percentage of bank alteration plotted against electrofishing-estimated numbers of existing trout longer than 6 inches, $n = 230$, all sites and years.

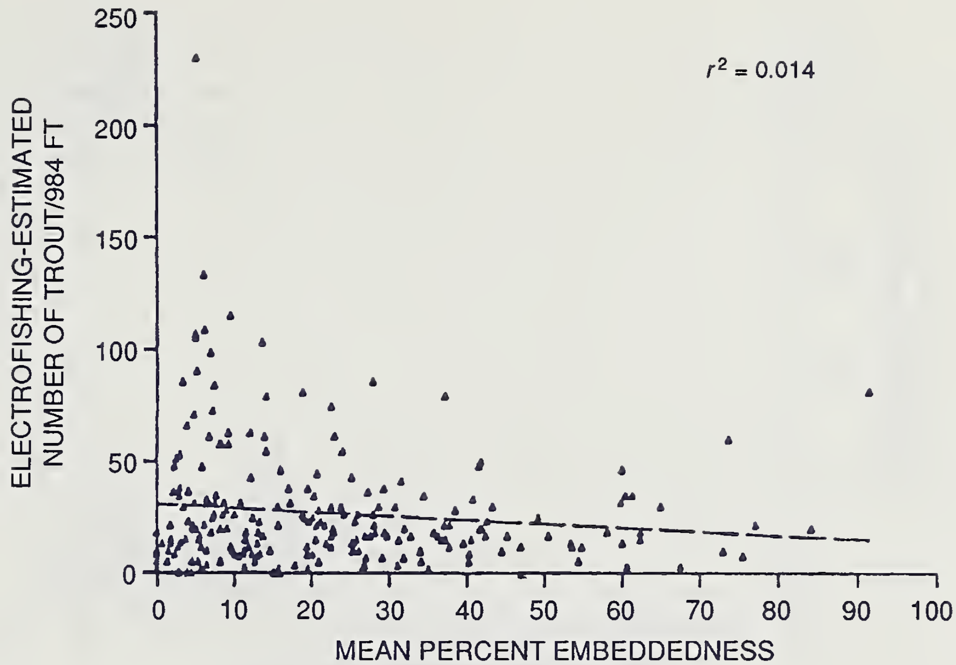

Figure 12—Percent embeddedness plotted against electrofishing-estimated numbers of existing trout longer than 6 inches, $n = 230$, all sites and years.

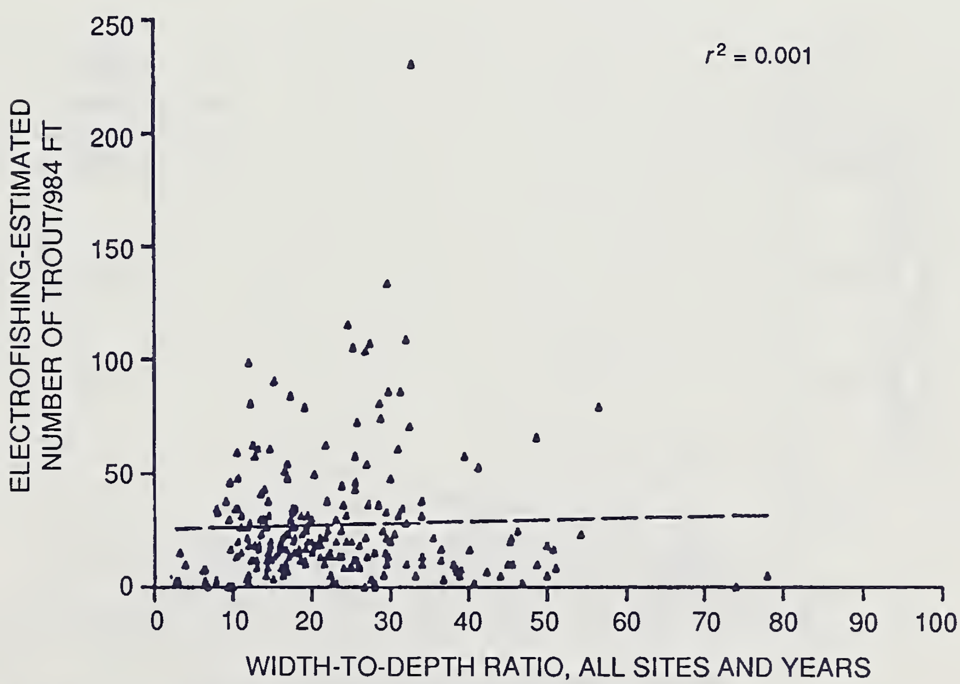

Figure 13—Width to depth ratio plotted against electrofishing-estimated numbers of existing trout longer than 6 inches, $n = 230$, all sites and years.

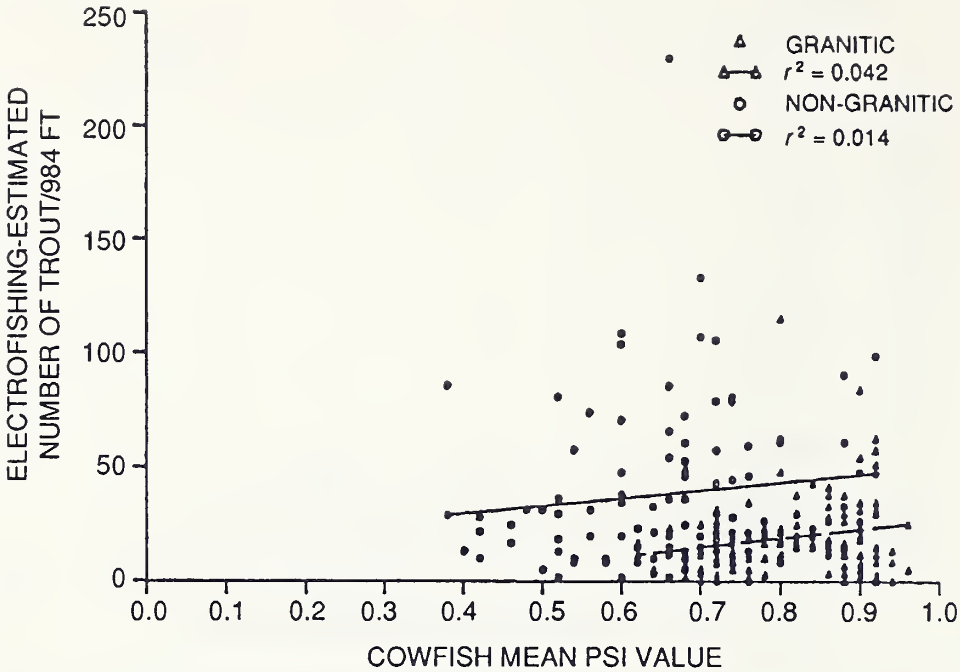

Figure 14—COWFISH mean PSI values plotted against electrofishing-estimated number of existing trout longer than 6 inches, $n = 230$, all sites and years.

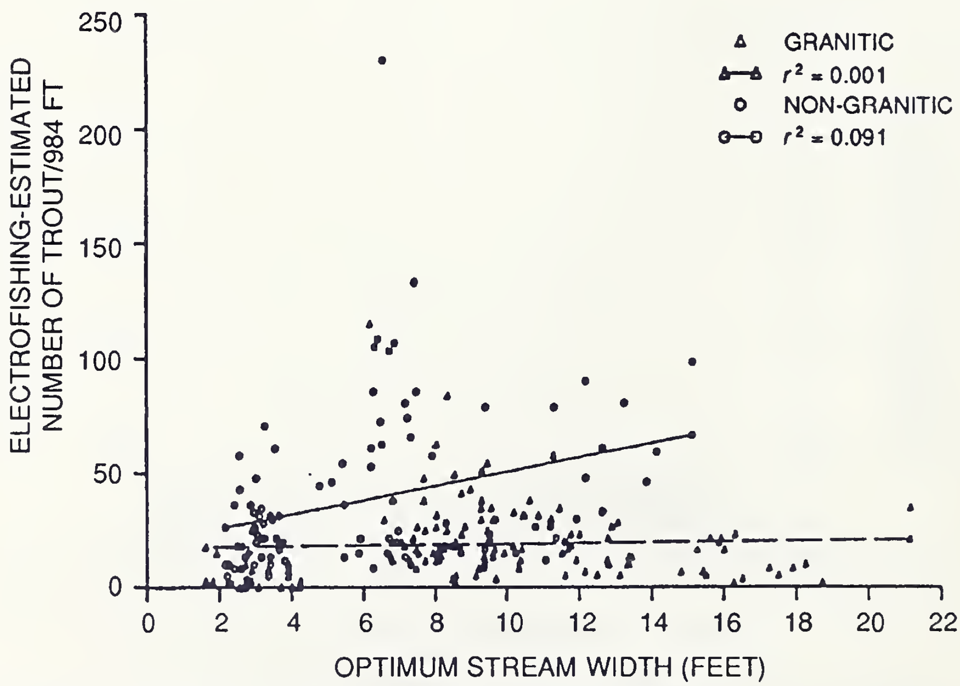

Figure 15—Optimum stream width (calculated as per COWFISH) plotted against electrofishing-estimated number of existing trout longer than 6 inches, $n = 230$, all sites and years.

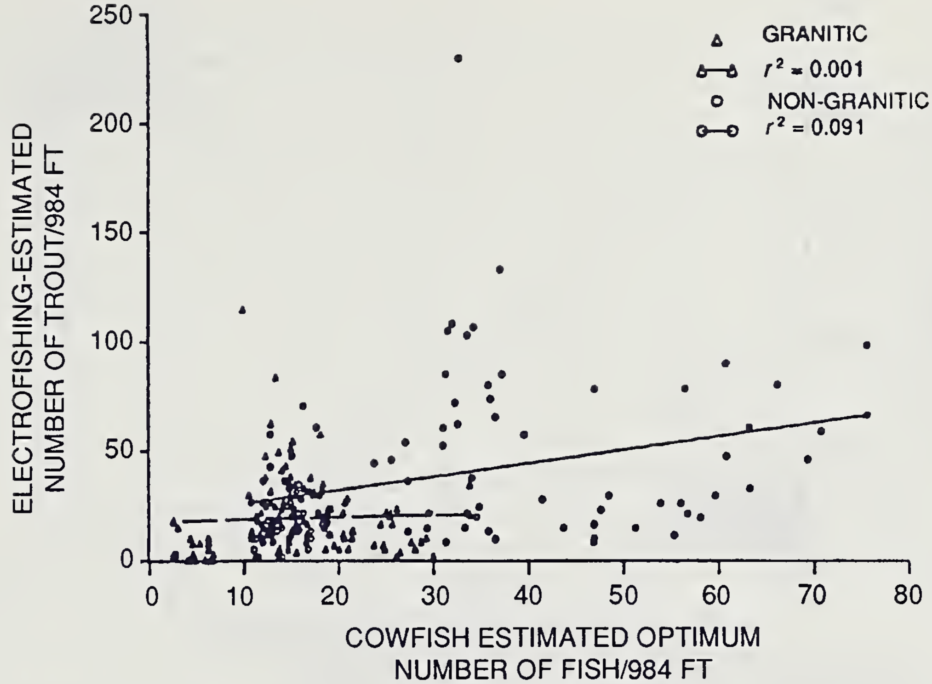

Figure 16—COWFISH estimated optimum number of fish/984 ft plotted against electrofishing-estimated number of existing trout longer than 6 inches, n = 230, all sites and years.

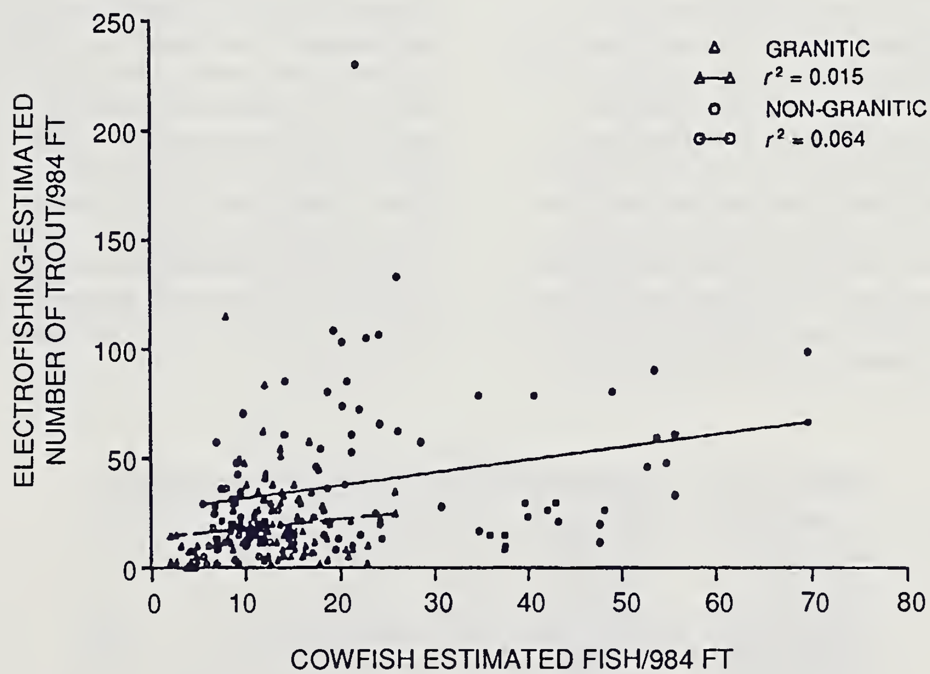

Figure 17—COWFISH estimated existing number of fish/984 ft plotted against electrofishing-estimated number of existing trout longer than 6 inches, n = 230, all sites and years.

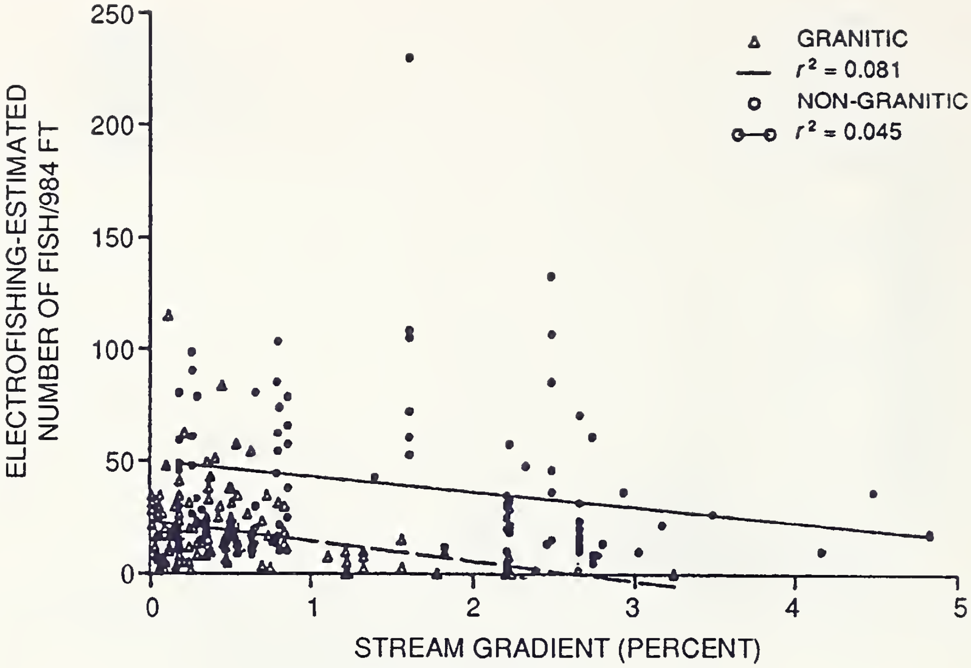

Figure 18—Stream channel gradient (percent) plotted against electrofishing-estimated number of existing trout longer than 6 inches, $n = 230$, all sites and years.

Our investigation of the stratification concept with individual streams and species showed no significant correlations in five of the six streams we studied. The stratification strategy worked in that it demonstrated COWFISH's utility with Otter Creek's brown trout. Estimates correlated significantly with actual fish abundance ($P < 0.01$, table 4 and fig. 19). It should be noted that one point does influence the relationship disproportionately, but the correlation was still significant at the 0.05 level when this point was ignored. Fifty percent of the variation in electrofishing estimates of existing fish abundance was explained by COWFISH estimates.

Averages of COWFISH's estimates for all sites and years for a given stream reach plotted against the averages of electrofishing estimates showed only a slight improvement in predictability ($r^2 = 0.19$, fig. 20). Populations of catchable trout do not appear to fluctuate around a mean value consistently predictable by COWFISH. Examination of figure 20 suggests the existence of three linear relationships that may be of interest. But when each of the points among the apparent lines was identified with the species, site, and other variables, no groups, clusters, or strings were expressed.

Table 4—Results of applying COWFISH to individual streams and species

Stream	Species	n	r^2	r	p
Otter Creek	Brown	15	0.521	0.71	<0.01
Tabor Creek	Rainbow	18	.021	.14	—
Gance Creek	Cutthroat	27	.060	.24	<.50
Frenchman Creek	Brook trout	24	.090	.30	<.20
Stolle Meadow	Bull trout	33	.005	.07	—
Johnson Creek	Brook trout	30	.001	.03	—

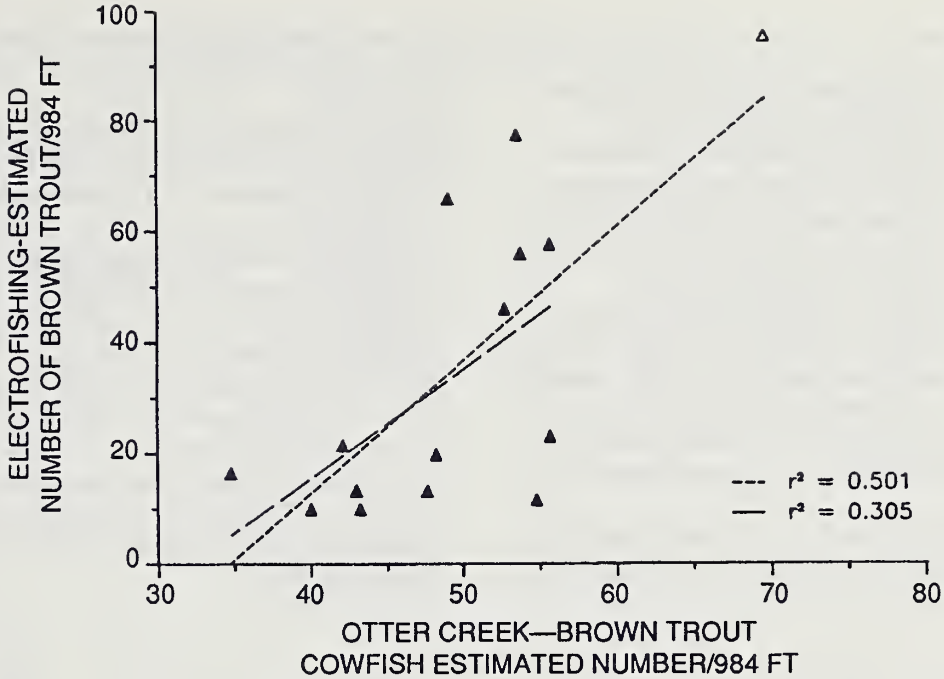

Figure 19—COWFISH estimated number of existing trout plotted against electrofishing-estimated number of existing trout longer than 6 inches, $n = 15$, all sites and years for Otter Creek.

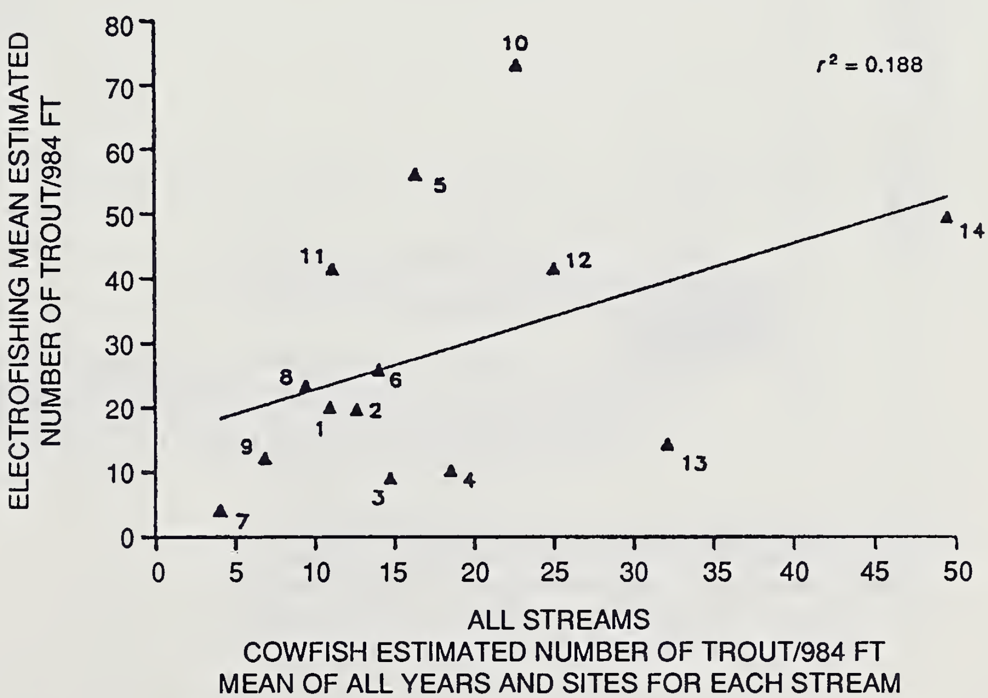

Figure 20—COWFISH estimated number of existing trout plotted against electrofishing-estimated number of existing trout longer than 6 inches, $n = 230$, mean of all sites and years for each of all the streams. Numbers by each data point coincide to the number of each stream on table 1 and figure 1.

Modifications

Our modifications did not consistently improve the significance of the relationships between COWFISH estimates and actual fish abundance. Without relationships between real trout populations and the input and output variables of COWFISH, adding coefficients to the model to correct the slope and *y*-axis intercept is meaningless.

The alterations of our initial methods, as suggested by COWFISH users, for estimating substrate embeddedness and streambank alteration, as well as the coefficients for estimating "optimum fish numbers" did not decrease the variability in predicting existing fish abundance. Compare figures 17 and 21.

When looking at 3-year means of estimates from individual streams and species with 6 or more years of data, COWFISH estimates do not have strong relationships to electrofishing estimates (table 5 and figs. 22-27).

The COWFISH manual states that as the percentage of rock increases in streambanks, predictive accuracy decreases. We hypothesized that we could use rock content as a decision criterion for applying COWFISH to a stream (assuming that rock content in the bank correlated with the rock content of the substrate). But we found no trends by plotting the percentage of large substrate against the difference between actual and predicted fish abundance (fig. 28). COWFISH predicts existing numbers of trout as poorly in the streams we examined with a high percentage of large substrate as those with no large substrate. Furthermore, the percentage of large substrate does not appear to relate to fish abundance (fig. 29).

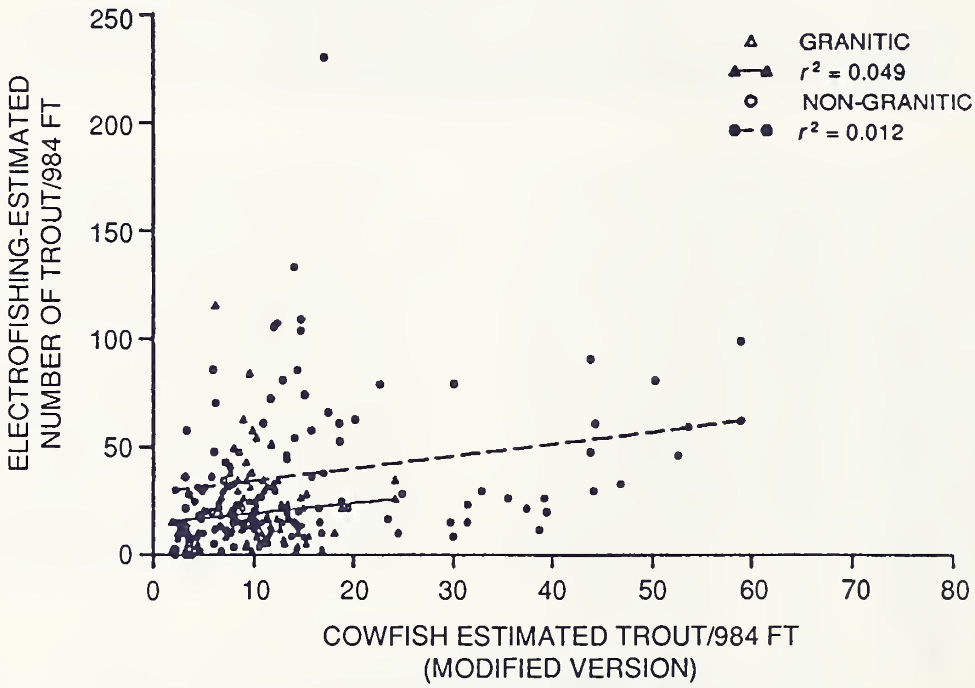

Figure 21—Modified version of COWFISH estimated existing number of fish per 984 ft plotted against electrofishing-estimated number of existing trout longer than 6 inches, n = 230, all sites and years (includes modifications recommended by COWFISH experts).

Table 5—The relationships between means from several years of fish abundances estimated by COWFISH and removal-depletion electrofishing methods for each of three sites

Stream	Years averaged	n	r^2	r	p
All streams combined	All Years[1]	14	0.19	0.44	<0.10
Johnson	75-79, 80-85	6	.08	–.28	—
Stolle Meadows	75-79, 80-85	6	.02	.14	—
Frenchman Creek; lower	76-79, 80-83	6	.28	–.53	<.50
Horton Creek	78-80, E2-84	6	.15	–.39	—
Gance Creek	78-81, 82-86	6	.20	–.45	<.50
Tabor Creek	78-81, 82-84	6	.03	–.17	—

[1]See table 1.

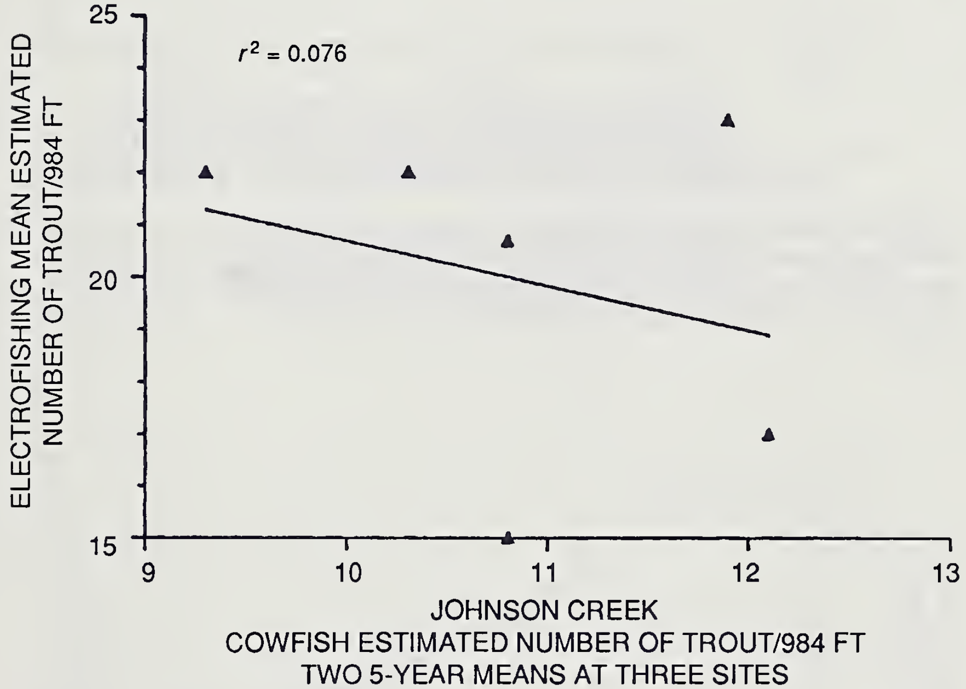

Figure 22—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, n = 6, two 5-year means at three sites for Johnson Creek.

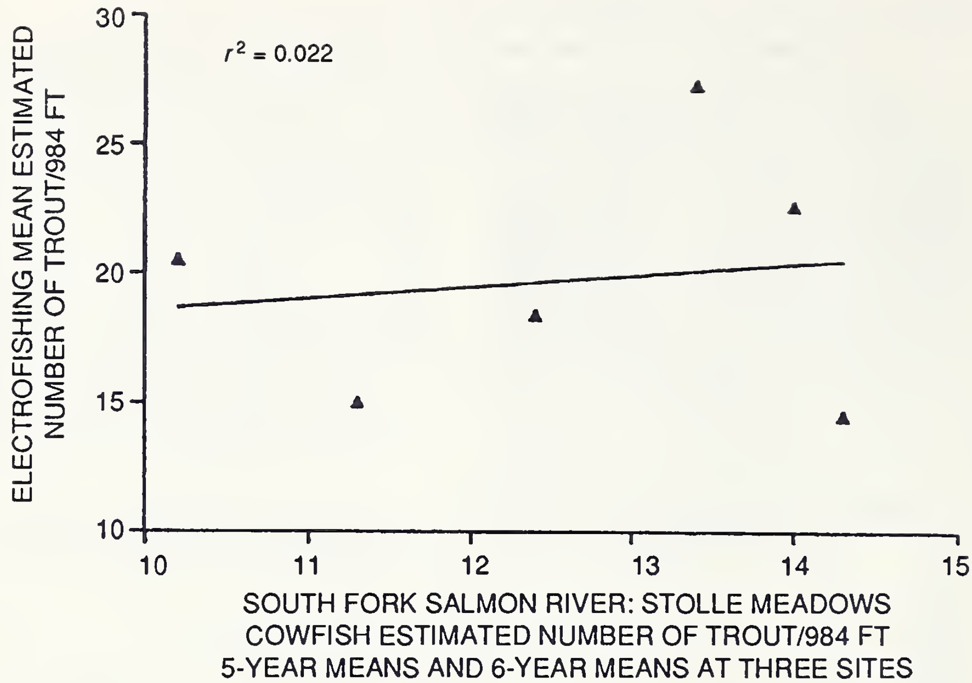

Figure 23—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, $n = 6$, a 5-year mean and a 6-year mean at three sites for Stolle Meadows site on the South Fork Salmon River.

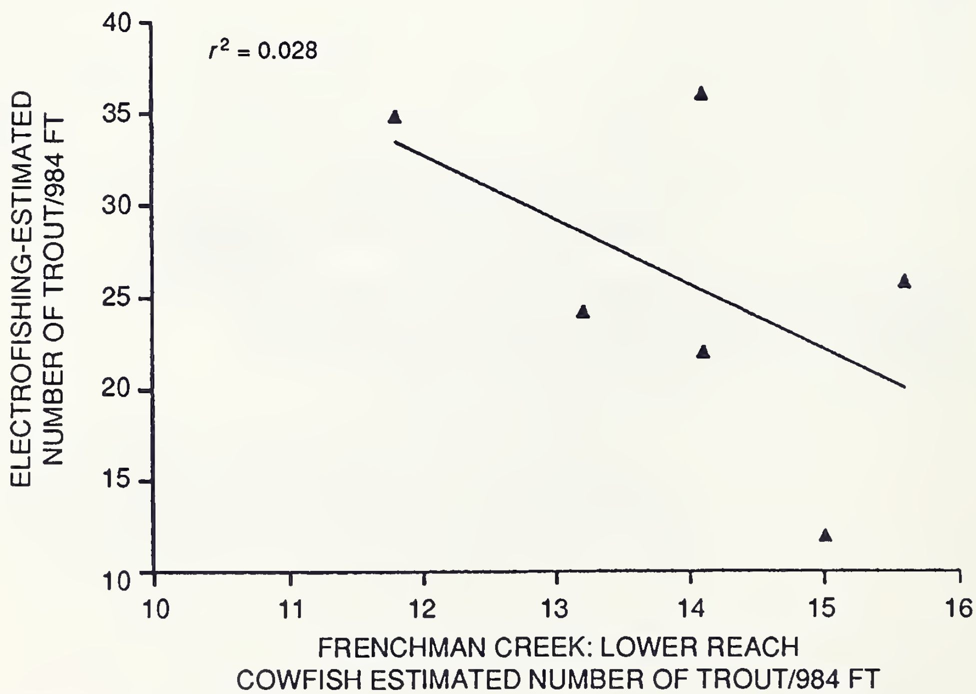

Figure 24—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, $n = 6$, two 4-year means at three sites for Frenchman Creek, lower site.

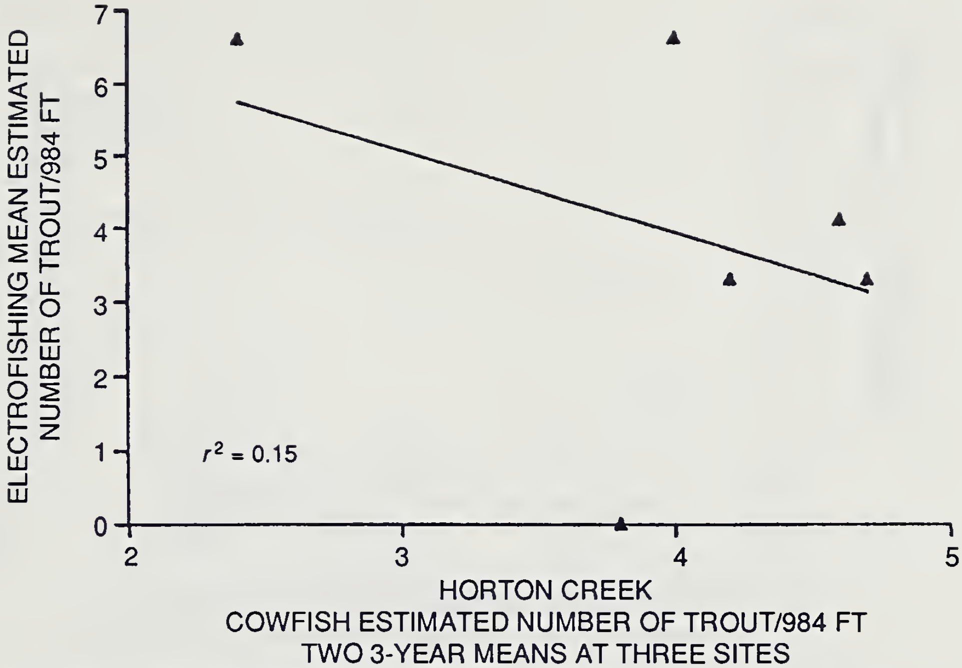

Figure 25—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, $n = 6$, two 3-year means at three sites for Horton Creek.

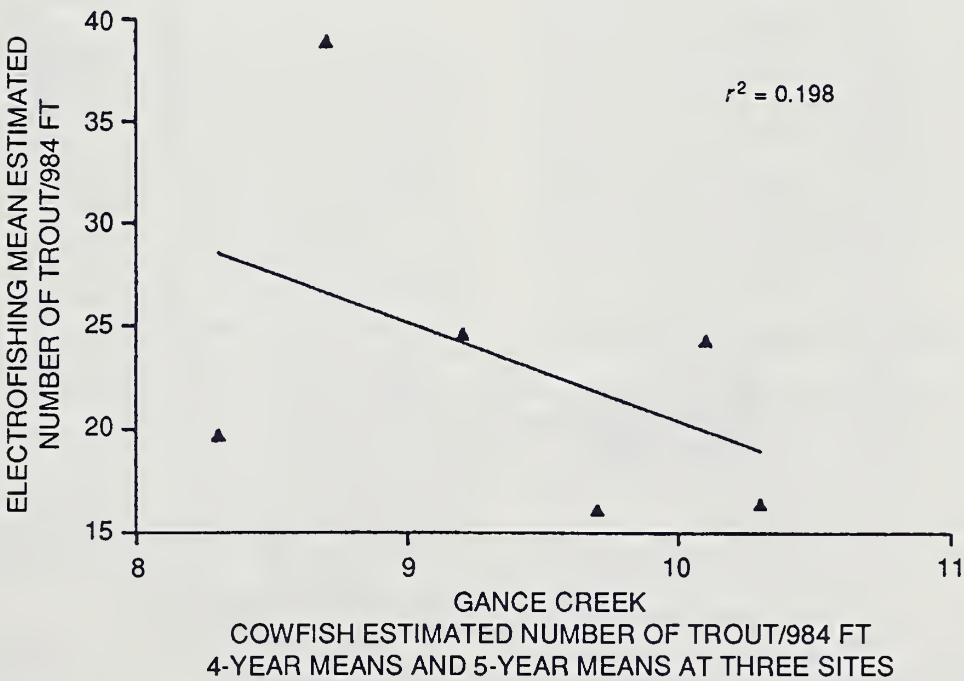

Figure 26—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, $n = 6$, a 4-year mean and a 5-year mean at three sites for Gance Creek.

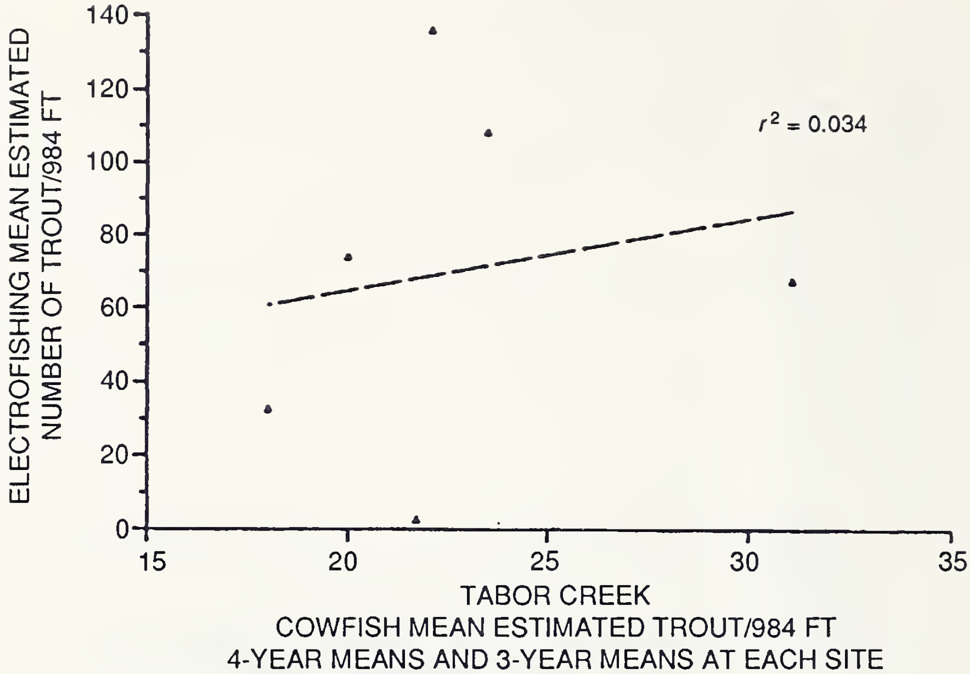

Figure 27—Means of COWFISH estimated number of existing trout plotted against means of electrofishing-estimated number of existing trout longer than 6 inches, n = 6, a 4-year mean and a 3-year mean at three sites for Tabor Creek.

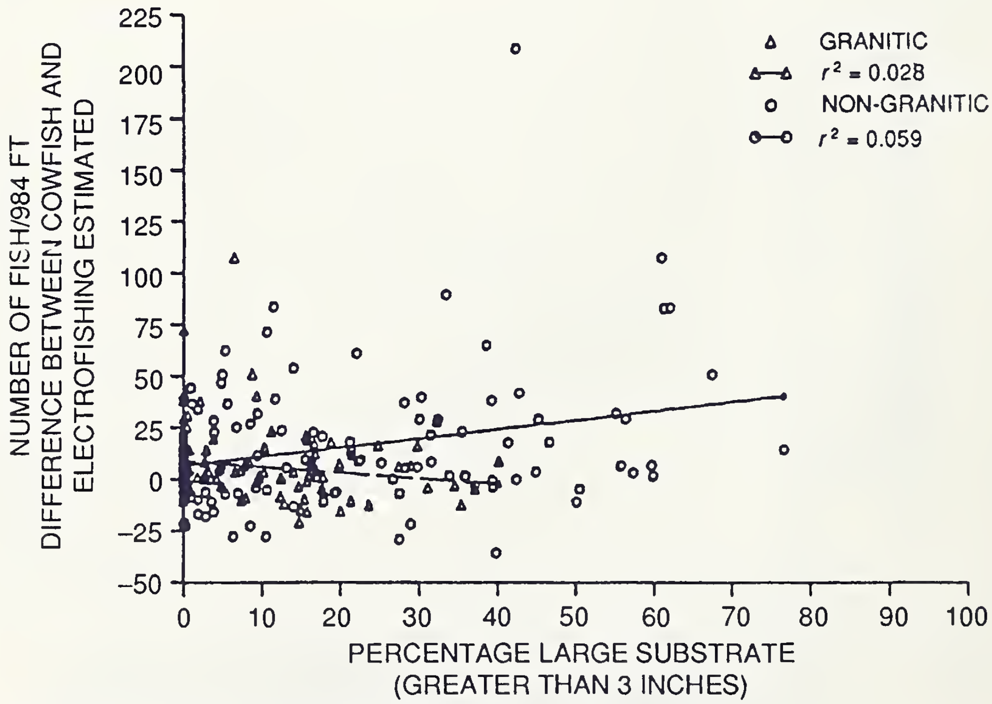

Figure 28—Percentage of large substrate (larger than 3 inches) plotted against the difference between electrofishing-estimated number of existing fish longer than 6 inches and COWFISH estimated number of existing fish, n = 230, all years and sites.

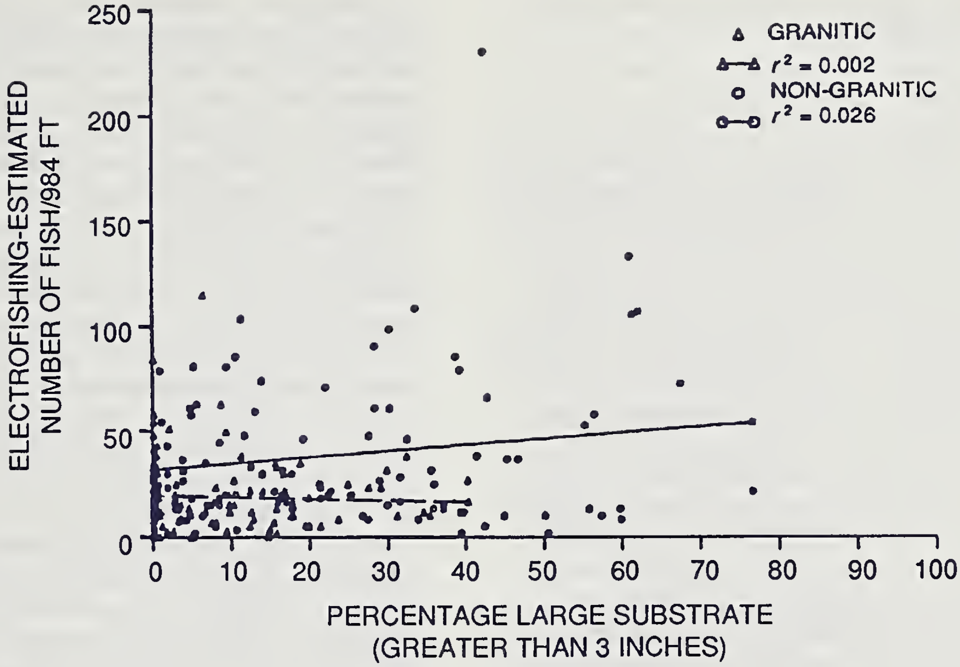

Figure 29—Percentage of large substrate (larger than 3 inches) plotted against the electrofishing-estimated number of existing fish longer than 6 inches, $n = 230$, all years and sites.

Sensitivity

Sensitivity testing showed that changing the percentage of occurrence of any one of the five PSI input variables by 10 percent changed the economic loss by 7 to 14 percent in lower Frenchman Creek. As percentage of occurrence of a habitat attribute ranged from 0.0 to 100, economic loss ranged from $9.75 to $45.00. Input was the percentage of occurrence of undercut banks, exposed soil, percentage of vegetational overhang, width-to-depth ratio, and percentage of embeddedness. Doubling stream width doubled the economic loss when the stream width/depth ratio was held constant with all the other variables. The model delineates only between gradients higher and lower than 5 percent; therefore response to changes in gradient was predictably stepwise. Fish loss and economic loss tripled when drainage classification changed from granitic to nongranitic.

DISCUSSION

Mechanics of the Model

The errors in the worksheets and ambiguity in the manual (Lloyd 1986; USDA 1986), while trivial in appearance, can introduce significant variation into stream evaluations. Although this flaw does not render COWFISH useless, it does suggest that results among users could vary considerably, depending on the manual used and the corrections made. An updated manual could eliminate these problems and also include improvements made by Shepard and others Shepard (personal communication, 1989) recommends that three (or more) 100-foot sections be used for evaluating each site, that each 100-foot section should be divided into five manageable 20-foot sections, and that the fish loss and economic portions of the model be dropped.

COWFISH Without Modifications

COWFISH did not work for the streams we studied with the algorithm provided in the manual or with the addition of suggestions by COWFISH users. We did not attempt to develop equations to adjust the slope or *Y*-axis intercept of the plotted relationships because the high degree of variability renders this procedure useless.

The above discussion does not indicate that COWFISH does not estimate population numbers satisfactorily in other streams or with other species. Shepard (1989) has shown COWFISH to be useful in the Beaverhead National Forest in southwestern Montana. When Shepard tested 43 sites in 39 streams, COWFISH explained 65 percent ($r^2 = 0.65$) of the variation in actual abundance for cutthroat and rainbow trout (combined together). Brook trout

abundance, as with trout in our streams, was less predictable ($r^2 = 0.14$).

Modifications

The utility of the model may be confounded by the fluctuations of fish populations derived from factors it does not measure. Fish populations can fluctuate widely in the Intermountain West (Platts and Nelson 1988). Intrinsic population fluctuations around a long-term mean carrying capacity can result from oscillations in fecundity, mortality, food, stress, and harvest. Interfluvial migrations for spawning or avoiding unfavorable conditions can also change fish numbers within a given reach.

Adding variables such as stream canopy, maximum summer temperature, streamflow variations, and exploitation may improve COWFISH's utility. Perhaps nutrient analyses and geomorphic measurements as done by Platts (1974), Lanka and others (1987), and Scarnecchia and Bergersen (1987) may aid in the classification of streams into groups with similar production. In the Great Basin, thermal input appears to be very important and may provide a useful measurement for predicting biomass (Platts and Nelson 1989).

Combining a model that predicts long-term mean production could be meshed with a population dynamics model that would incorporate some of the nuisance variables confounding COWFISH. This would change the complexity and usability of COWFISH, but it may be necessary in order to reasonably predict optimal and existing trout abundance in streams.

A potentially important modification may come from determining the most appropriate measure of fish abundance. Platts and Nelson (1988) found that salmonid populations in the Rocky Mountains and the Great Basin fluctuate differently in terms of numerical abundance and biomass. Where no strong relationships exist with the numbers of fish per 984 feet, a stronger relationship may exist with numbers per cubic foot or biomass per cubic foot. The latter may prove to be more predictable and increase the utility of COWFISH.

A possible modification of the COWFISH concept might include a risk model that would estimate the stability of a stream system during extreme flow events. Streams reflect the management or mismanagement of their respective watersheds. The importance of vegetation is well documented for maintaining infiltration and reducing erosion, gullying, and overland flow (Berry and Goebel 1978; Beschta and Platts 1986; Dickinson and Scott 1978; Medina and Martin 1988; Platts 1981; Platts and others 1985).

Extreme flow events through degraded riparian corridors threaten fish and wildlife habitat. After an extreme flow event, the loss of habitat and pasture land is often blamed on the event and not poor management practices. Under excessive grazing, streambanks have little vegetation and poor vegetation development for stabilization (Schuster 1964; Svejcar and Christiansen 1987) as well as reduced insulative cover to prevent and reduce freeze-thaw related damage (Bohn 1989). Degraded uplands also have reduced vegetation cover and increased soil compaction, which decreases percolation and ground water recharge and increases overland flow (Smiens 1975). Small and local effects of grazing may rehabilitate within 5 to 25 years (Keller and others 1979). But an entire system can "blow out" if an extreme event occurs on overgrazed, compacted, and devegetated uplands, resulting in high flows through unstable stream channels. Healthy riverine riparian areas can actually improve during extreme events (Hancock, 1989; Platts and others 1985). Converting COWFISH into a risk-probability model may help sensitize users and managers to the risks of degrading streambanks and vegetation in the riparian and upland areas.

COWFISH could prove more useful in evaluating the "health" of stream and riparian habitats without estimating fish or economic losses. COWFISH could be used for comparing alternatives rather than predicting losses. Until COWFISH is developed further, it may best serve as a general guideline to demonstrate what criteria are associated with "healthy" stream-riparian systems and how far a system has deviated from its optimal state. This is possibly a more reasonable objective for COWFISH because most Federal agencies manage habitat and not fish or wildlife populations. Harvest, seeding rates, and population fluctuations are beyond the responsibility of most Federal land managers.

There is also a potential time-series problem when using COWFISH. Bohn (1986, 1989) found that, on areas with season-long grazing, much of the bank damage occurred during the winter from soil freeze-thaw events or instream ice events. Although it is appropriate to evaluate grazing impacts immediately after grazing in late summer, all of the effects of that summer's grazing may not be apparent until after one or more winters. If grazing management changes in the interim, the most recent management practice may be incorrectly associated with the damage caused by freeze-thaw and icing events of the previous winter, which were actually a result of earlier management practices.

Putting a monetary value on fish masks the extreme value of riparian areas to society and

livestock operators. It does provide a bargaining tool, and its use may be justified and advantageous at times. Riparian communities in good health have higher water tables for more consistent and perennial flows, produce more and better livestock forage, and maintain resilient streambanks during floods so that valuable pasture lands and topsoils are not eroded and replaced by wide, flat gravel bars (Marcuson 1977; Rosenboom and Russell 1985). Healthy riparian complexes provide quality fish and wildlife habitat for spawning, nesting, rearing, and migration corridors as well as recreational opportunities and economic benefits (Moring and others 1985).

A healthy stream-riparian complex has intangible and intrinsic values similar to that of fine art. Many of these values are masked when the cost of habitat degradation is tabulated as it is by COWFISH on the basis of fish alone. Putting a dollar value on these systems is useful, but the monetary evaluation of one portion of the resource should not exclude other monetary or esthetic values. Long-term benefits of healthy riparian-stream systems may not outweigh short-term economic advantages of overgrazing when benefits are tabulated only in terms of fish. If a single attribute receives too much economic emphasis, abusive management may appear to be economically sound.

Sensitivity

Changing the occurrence of a single attribute by 10 percent changed the output by 7 to 14 percent (everything else held equal). This appears to be acceptable if gradient and drainage type are correct and the total sum of the mean error of estimation was less than 10 percent. But the change in COWFISH's estimates will be substantial if an observer consistently underestimates each attribute by 10 percent on one sample date and another observer consistently overestimates each attribute by 10 percent at a later date. Land managers would not be certain if changes in COWFISH estimates reflect changes in habitat or changes in observation accuracy and precision.

Shepard (1989b) found that when six different crews rated the same stream, HSI estimates ranged from 54 to 62, with a mean of 60. Crews were made up of a wide variety of professionals with backgrounds in fisheries, wildlife, forestry, range conservation, and wildfire management. Some members of each crew had never used COWFISH before. This suggests that the visual estimates are probably adequate if errors are consistent and measured for each individual. By checking an individual's observations against a known (measured) stream section, an evaluator would know the accuracy and precision of each observer. Differences in mean error can be altered with adjustments of coefficients if estimates are as consistent as Shepard's results indicate. Nevertheless COWFISH does not specify verification of personnel and it is doubtful that observer's estimates have been calibrated in the field. Verification should be repeated occasionally as observer-bias and variability can change with experience. Without an estimate of observer-error, it is not possible to decide whether the changes in COWFISH estimates from year to year are due to changes in habitat attributes or due to differences in observation. Ocular estimates can be used only if carefully verified, as demonstrated by Hatton and others (1986) and Hankin and Reeves (1988).

Current Status of COWFISH

COWFISH is apparently working satisfactorily for managers in Montana. Shepard and others are continuing to improve it for the streams they manage (Shepard 1989a). Currently, COWFISH may be best developed into a tool for approximating stream-riparian health and not for estimating fish abundance or economic tradeoffs. To be successful at estimating fish abundance, COWFISH needs to be modified before it will work on the streams we examined. If the objective is to predict actual fish populations in streams with complex fish population dynamics, fish movements, and harvest rates, then the model must account for these nuisance variables. To meet these objectives, COWFISH will become complicated and cumbersome. For estimating existing fish abundance, electrofishing capture-depletion methods are probably more useful, certainly more reliable, and only slightly more difficult than using COWFISH.

The objectives of COWFISH need to be reevaluated before development continues in the Intermountain West. Its purpose is to indicate stream-riparian health and to help sensitize range managers to the influences of livestock grazing on stream-riparian habitat. COWFISH is designed to estimate optimum and existing fish abundance and associated economic loss. Perhaps by ending the analysis at the Habitat Suitability Index and not calculating optimum and existing fish abundance, fish loss, and economic loss, COWFISH would be more useful.

SUMMARY

1. COWFISH appears to work satisfactorily in Montana for rainbow and cutthroat trout but has little predictive value for estimating existing fish numbers in the streams we studied.

2. No modifications that we applied consistently increased COWFISH's predictability. Future

modifications of a larger and more fundamental nature may prove successful.

3. COWFISH did successfully predict hatchery brown trout numbers in Otter Creek. The model was unsuccessful with five other streams individually tested with data from multiple sites and years. Examining streams and trout species individually will allow COWFISH to be used where it is currently suited and will allow further modifications where it is not suited.

4. COWFISH may sensitize users and managers to the impacts of livestock grazing on fish populations, but it could mask the risks of extreme events occurring on degraded systems. If used incorrectly, COWFISH may also backfire and desensitize users and managers to the impacts of livestock grazing on fish populations because of violated assumptions and poor predictive ability.

5. The future of a COWFISH-type model may be to estimate the health of streambank-channels and riparian complexes. Expanding COWFISH into a population estimation model may necessitate the inclusion of a complex matrix of data, including population dynamics, seeding levels, migrations, harvest rates, and other nuisance variables that appear to confound the current model.

6. Emphasis of COWFISH on the economic value of fish may be justified in streams where it satisfactorily estimates fish abundance. Estimates of economic losses based only on fish must be used carefully so that they do not mask other intrinsic and intangible values of healthy stream-riparian-meadow complexes. The possibility exists that, if other riparian values are not considered, abusive management may appear to be a sound decision. Certainly similar decisions have been made in the past as demonstrated by the current poor condition of many riparian systems throughout the West (USGAO 1988).

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The COWFISH model, developed and applied in selected Montana streams, was tested on 14 streams in Idaho, Nevada, and Utah, where it proved to have little value for predicting numbers of trout in watersheds grazed by livestock. The model holds promise for estimating the health of stream channels and riparian complexes.

KEYWORDS: fish habitat, livestock grazing, habitat suitability index, model testing

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The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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